SIZE VARIATION OF CENTRAL AND WESTERN PACIFIC YELLOWFIN TUNA

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ABSTRACT

This analysis of the size frequencies of longline-caught yellowfin tuna, Neothunnus macropterus (Temminck and Schlegel), is based on weight data collected in the Honolulu market from 1948 to 1953 for Hawaiian waters, and on measurements taken aboard research vessels from 1951 to 1954 for the central equatorial Pacific and aboard Japanese tuna motherships in 1950 and 1951 for the western equatorial Pacific. The modes which occur in the size-frequency distributions for these three areas are all in similar positions, but certain modal groups present in the Hawaiian material are frequently or consistently missing from the central and western equatorial samples. In both the Hawaiian and equatorial areas there are no important differences in the size composition from year to year.

Smaller yellowfin (100-130 pounds) enter the Hawaiian fishery in June and July, and the larger fish (over 130 pounds) appear in August and September.

Progression of the modes in the Hawaiian samples indicates growth, with the rate slackening in the latter half of each year. No such modal progression appears in the data from equatorial waters.

Male yellowfin in Hawaiian waters attain greater size than do the females, and they usually make up about 64 percent of the fish taken by longline. Similar sex ratios and size differences between the sexes are found in the samples from equatorial areas.

CONTENTS

ILLUSTRATIONS

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The yellowfin tuna, Neothunnus macropterus (Temminck and Schlegel), is an important commercial species in many areas of the Pacific, and it is of interest to know whether the stocks differ biologically from one area to another. Since some aspects of the life history of a fish can be inferred from the sizes of the fish caught by a standard type of gear, we have herein assembled a number of size frequencies classified by area, sex, and season, and have examined them for evidence of growth and migration.

Moore (1951) studied the age and growth of Hawaiian yellowfin by the size-frequency method. Using data collected at the Honolulu market in 1948 and 1949, he demonstrated rapid growth amounting to about 60 pounds per year. Additional Hawaiian market data for the years 1950-53 considered herein support Moore's findings on the growth of the fish and also provide evidence of a migration of the yellowfin in this area. In addition, yellowfin size-frequency data from along the Pacific Equator are examined for evidence of growth and migration.

Appreciation is expressed to the members of our field parties who have collected measurements of the tunas. So many persons have assisted by gathering data and offering suggestions that no attempt will be made to name and thank them individually. Mr. T. Nakata prepared the figures in this report.

SOURCES OF DATA

All yellowfin considered in this report were caught by longline (flagline) gear. In Hawaii, where there is a commercial longline fishery, described in detail by June (1950) and Otsu (1954), the landings at the market were sampled as reported by Moore (1951). In addition the Pacific Oceanic Fishery Investigations (POFI) has carried out exploratory fishing operations[1] in the central Pacific using longline fishing gear[2] described by Niska (1953). One sample is available from a commercial venture in Samoa (Van Campen 1954). Additional size-frequency data from the western Pacific are available from Japanese mothership expeditions. These fishing expeditions were reviewed in detail by Shimada (1951a and b), Ego and Otsu (1952), Van Campen (1952), and Murphy and Otsu (1954). The general areas from which these various samples were obtained are shown in figure 1.

APPLICABILITY OF THE SIZE-FREQUENCY METHOD

Most of the conclusions drawn in this report are dependent on the positions and changes in positions of size-frequency modes. There are a number of biological characteristics of the yellowfin other than those we wish to describe that may affect the size distributions and modal positions.

Samples of a schooling fish may not be representative of the stock present in any area if the samples are small in number and/or poorly distributed. Murphy and Elliott (1954) have studied variability in longline catches of yellowfin in the central Pacific, and they report that "there is considerable evidence that yellowfin tuna are not randomly distributed in space but rather are aggregated." Schaefer (1948), referring to the difficulty involved in using the modal progression method of growth analysis, says "it is desirable that the total sample be composed of subsamples drawn by either representative or random methods from each of a large number of schools selected

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1/ Measurements of the catches taken aboard the POFI research vessels John R. Manning and Hugh M. Smith and the cooperating commercial vessel North American have been used in this study.

2/ In general the fishing gear of the Japanese, Hawaiian, and POFI vessels is made of cotton and has 4 to 6 branch lines per basket. However, POFI has experimentally varied the number of hooks per basket from 6 to 21. Comparison of samples between this experimental gear and the standard 6-hook gear indicates that the type of gear had no appreciable effect on the size of the fish caught.

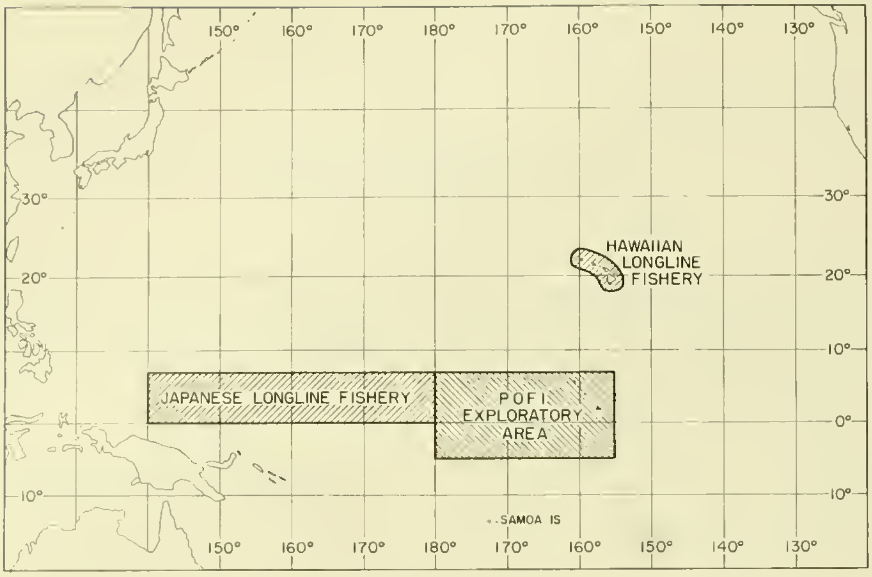

Figure 1. --Fishing areas from which data were obtained.

randomly from the population." Since most of our samples consist of a number of small catches from many fishing stations well separated in space, they probably fulfill this requirement.

Even large, well-distributed samples may not be representative of the size composition of a migratory population. Although fishing effort in the vicinity of the Hawaiian Islands is roughly constant throughout the year, there is a marked increase in the catch of yellowfin during May to September, indicating a probable migration into and out of the fishery (Otsu 1954). If yellowfin available to the fishery at different times have different growth rates, the analysis will not describe growth accurately.

We must also recognize that no matter how well distributed in time and space the samples may be, longlines do not catch small fish and thus provide little or no information on the early life. Moreover, in the frequency distributions of larger adults the modes are closer spaced and more difficult to distinguish than in the smaller juveniles.

Another complication is the protracted spawning period of the yellowfin. Although the most active spawning period may be during the summer months, equatorial yellowfin with running milt have been observed the year around (Shimada 1951a). It has been suggested by Schaefer and Marr (1948) that "several batches" of eggs are spawned over an extended period of time. June (1953) notes that "individual fish /yellowfin/ mature more than one group of ova and have several spawnings during the same season in Hawaiian waters." His 1950 observations showed that spawning extended from around the middle of May to the end of October. Wade (1950) indicated that the spawning of yellowfin tuna extends from May to August in the Philippine region. As the result of such a prolonged spawning period, modal groups may be extended and ill-defined, making size-frequency distributions difficult to analyze.

In addition to these difficulties, male yellowfin taken by the longline are larger than females. Many of the measurements used herein are not accompanied by sex data, and although failure to separate the sexes may not cause serious errors in interpretations, it will certainly increase the variance of modal groups and make it harder to define them. It is also possible for modes to shift with time, not through growth, but simply by changes in the sex ratio in the sampling area. As will be shown, this danger does not seem to apply in the present instance, although caution must be exercised in interpreting changes in the modal groups of unsexed samples.

METHODS

The lengths of nearly all equatorial samples were taken in millimeters (some to the nearest whole centimeter) measured from the tip of the snout with jaws closed to the median portion of the caudal fork (with the fleshy flap depressed), as described by Marr and Schaefer (1949). These length measurements

were combined in 2-centimeter groups. The Honolulu market sizes, obtained in pounds, were combined into 10-pound weight groups for analysis. Tables 3 through 10 (Appendix) contain all of the grouped measurements.

Prior to locating modes, the data were smoothed by a three-item moving average and the following criteria were imposed:

1. No modes shall be recognized in distributions containing less than 100 fish.

2. Each mode shall be separated from every other mode by troughs dipping at least five fish below modal peaks after smoothing.

3. Each mode must be present in the data for at least two adjacent months (Hawaiian data only).

4. At least two of the frequency classes making up a modal group must contain no less than 15 individuals each before smoothing, or at least 10 individuals if the mode is present in two adjacent months.

5. The mode shall be the peak of the smoothed distribution or the center of two or more minor peaks which differ by less than five fish in height.

INTERPRETATIONS OF SIZE FREQUENCIES

Yellowfin from the Hawaiian Islands and those from various areas along the Equator differ widely in average size. Hawaiian fish are the largest, on the whole, and there is an increase in size from west to east along the Equator (Murphy and Shomura 1953). In view of this, three areas were examined independently: Hawaii, central equatorial region (155°W. to 180° longitude), and the Trust Territory or western equatorial region (134°E. to 179°E. longitude).

Hawaiian Yellowfin

Sexual Differences in the Catch

The mean size of the males is greater than the mean size of the females in the dominant size groups sampled by the longline. For the fish sampled at the Honolulu market from April through September, 1951, the dominant female modal group is centered at about 120 pounds and that of the male at about 130 pounds (fig. 2). Associated with the difference in mean size is an inequality in the sex ratio, for example, the fish examined from November 1950 through October

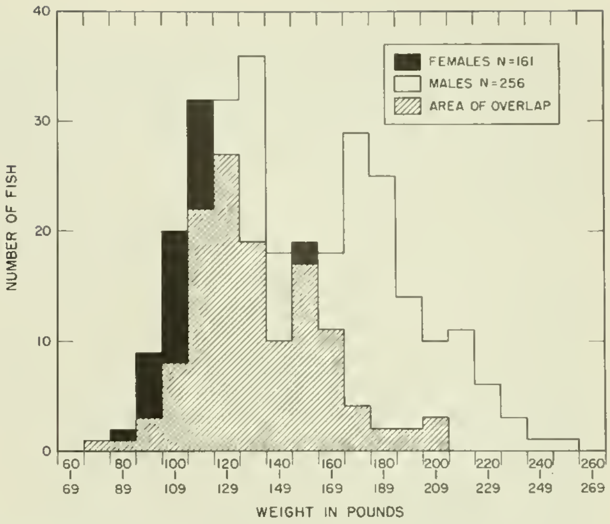

Figure 2.--Weight-frequency distributions of Hawaiian yellowfin, April-September 1951.

1951 had an average ratio of 1:06 in favor of the males (table 1). Monthly ratios do not deviate sufficiently to appreciably affect the positions of the modes in unsexed samples, although there is some indication that the predominance of males is greater from October through February.

Table 1.--Monthly sex ratios of Hawaiian yellowfin

Month	Numbers of each sex		Ratio of
	Males	Females	♂ : ♀
1950			
November	35	13	1:0.4
December	36	21	1:0.6
1951			
January	10	2	1:0.2
February	16	5	1:0.3
March	5	9	1:1.8
April	19	10	1:0.5
May	48	31	1:0.6
June	99	64	1:0.7
July	93	67	1:0.7
August	82	46	1:0.6
September	74	38	1:0.5
October	30	7	1:0.2
Total	547	313	1:0.6

A change in sex ratio with increasing size has been discussed by workers concerned with the equatorial region (Nakamura 1949, Shimada 1951a, Murphy and Shomura 1953, and Otsu 1954). They indicate that near the Equator yellowfin under 80 or 90 pounds have

a 1:1 sex ratio, while larger fish are predominantly male, as they are in Hawaii. This change in the sex ratio with increasing size may also occur in Hawaii but it will have little effect on the present analysis because the majority of the Hawaiian specimens are considerably larger than 80-90 pounds.

Sex-linked differences in abundance and growth have been investigated in other species of tuna. Brock (1943) states that there was no significant difference in the length of male and female albacore, Germo alalunga (Gmelin), from Oregon. He found the sex ratio to be 1:1 in fish above 67 cm. Below 67 cm. males apparently predominate, but he points out that "some of the smaller females were wrongly called males." Brock (1954) reports a 1:1 sex ratio for Hawaiian skipjack, Katsuwonus pelamis (Linné), during the months of March to August, but during September to December there were significantly more males.

Interyear Size Variation

Evidence of interyear size variation was sought in the largest samples for the years 1948-1952, i.e., June-September. The grouped weights for the four months of each year, plotted as deviations from the 5-year average (fig. 3), show that there are between-year differences in the abundance and position of certain size groups. However, the variations in abundance are small and there seem to be no trends in the positions of modal groups that would bias a growth curve based on the pooled data for all five years.

Intrayear Size Variation

Kishinouye (1923), in speaking generally of scombroid fishes from Japan, stated, "large and old are caught at the beginning of the fishing season, while at the end of the season only young and small ones are found." In the Hawaiian fishery there is an indication that the smaller yellowfin (100-130 pounds) enter the fishery early in the season (June and July) and larger fish (>130 pounds) appear a short while later (August and September). This can be seen in figure 4, which shows the percent deviations of individual months from the 4 months' mean (June-September) averaged over 5 years (1948-1952). This differential recruitment is not believed to affect the interpretation of growth because the absolute deviations are not great.

Moore (1951) remarks that the catches of the last 3 months of the year "were not large in comparison with the catches of the summer months," causing erratic modes to appear.

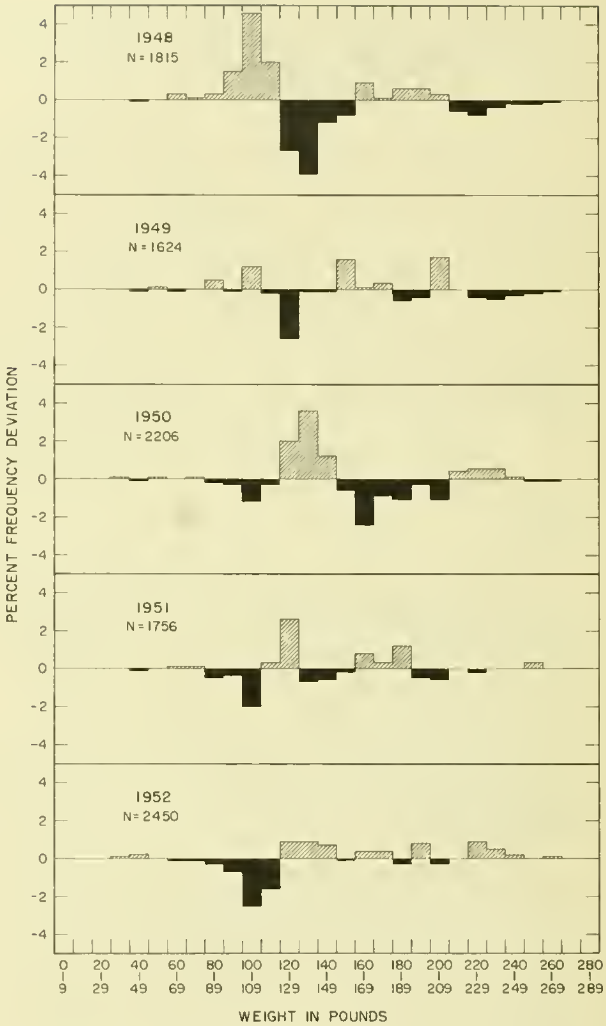

Figure 3. --Percent deviations from a 5-year average of Hawaiian yellowfin weight-frequency distributions for individual years (pooled samples for June-September).

The catches of the early months of the year are also very small, and they too may introduce this complication. This is illustrated by the typical monthly weight-frequency distributions for 1949 (fig. 5).

Moore's use of percentage deviation to follow the progression of modes through the year may have biased the interpretation of the modes in giving undue emphasis to the very small samples obtained early and late in the year; this may be especially true for the livebait-caught fish (fig. 5). This does not necessarily mean that small, indefinite modal groups which may appear for a few months are due to chance variation. They may or may

not be real, but, in any case, the location of the modes of these small groups may not be representative of the population. By using absolute rather than percentage deviations, by adhering to the criteria for distinguishing a mode given earlier in this report, and by omitting the livebait-caught fish used by Moore it was impossible to find significant modes in every month of the year for any individual year. For these reasons and in view of the relatively small interyear variation, it was decided to combine all years by months.

Figure 6 illustrates the distributions of weights by months obtained by combining all data, 1948-1953. From April through October only a single mode can be clearly identified, but from November through March two modes are in evidence and in January there is an indication of a third. During February and March there are abberant modes at 145 and 140 pounds respectively. These probably reflect the erratic positions of the modes in the very small samples which were combined to make up this size distribution.

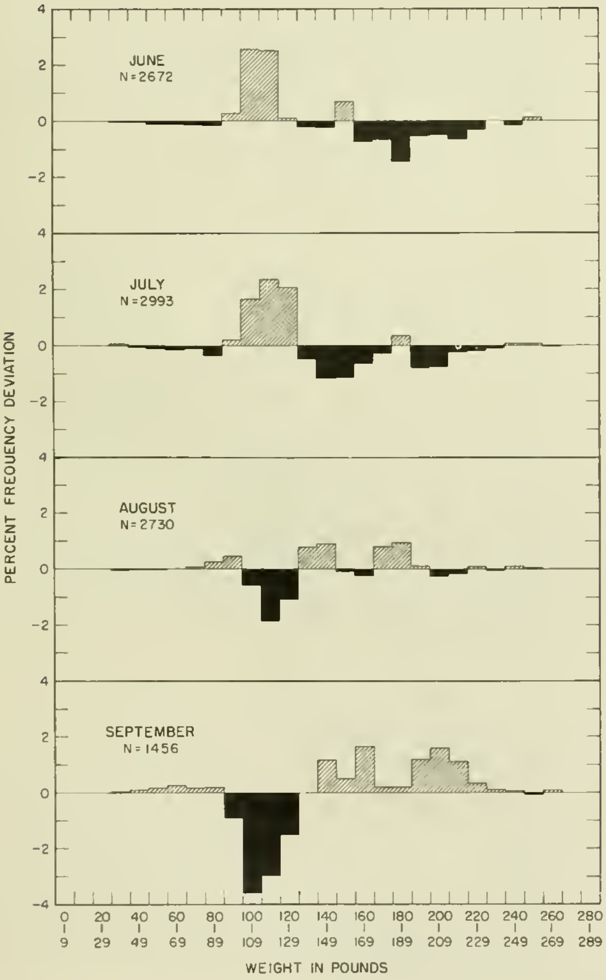

Figure 4. --Percent deviations of Hawaiian yellowfin weight-frequency distributions for individual months from a 4-month mean (June through September) averaged over 5 years (1948-1952).

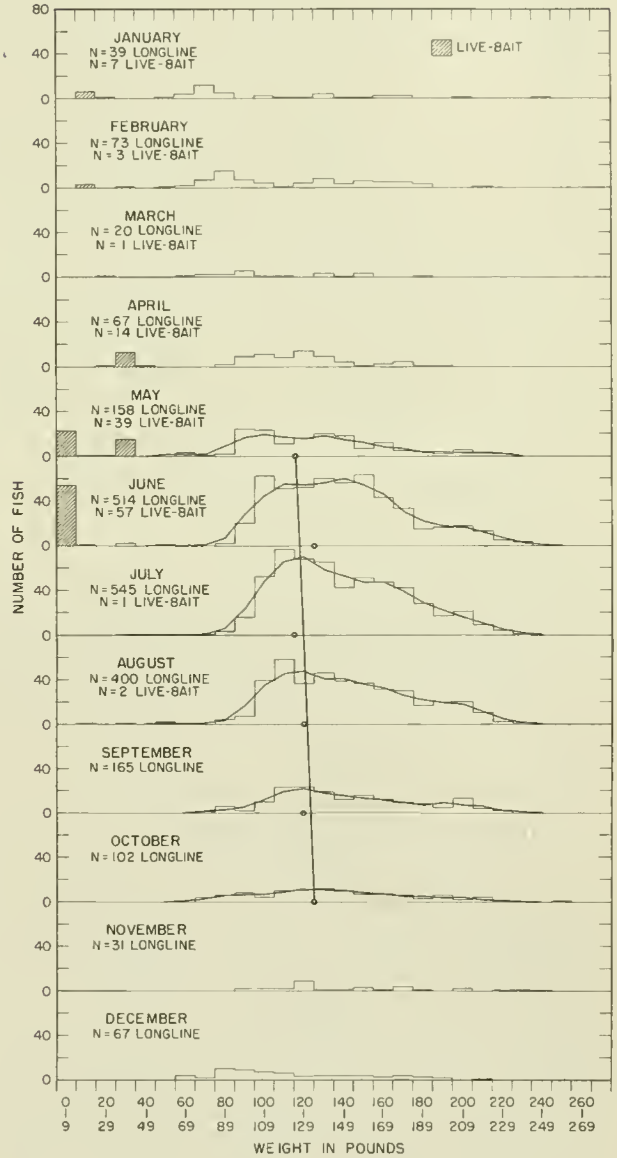

Figure 5. --Monthly weight-frequency distributions of Hawaiian yellowfin for 1949. Data taken from Moore (1951:147).

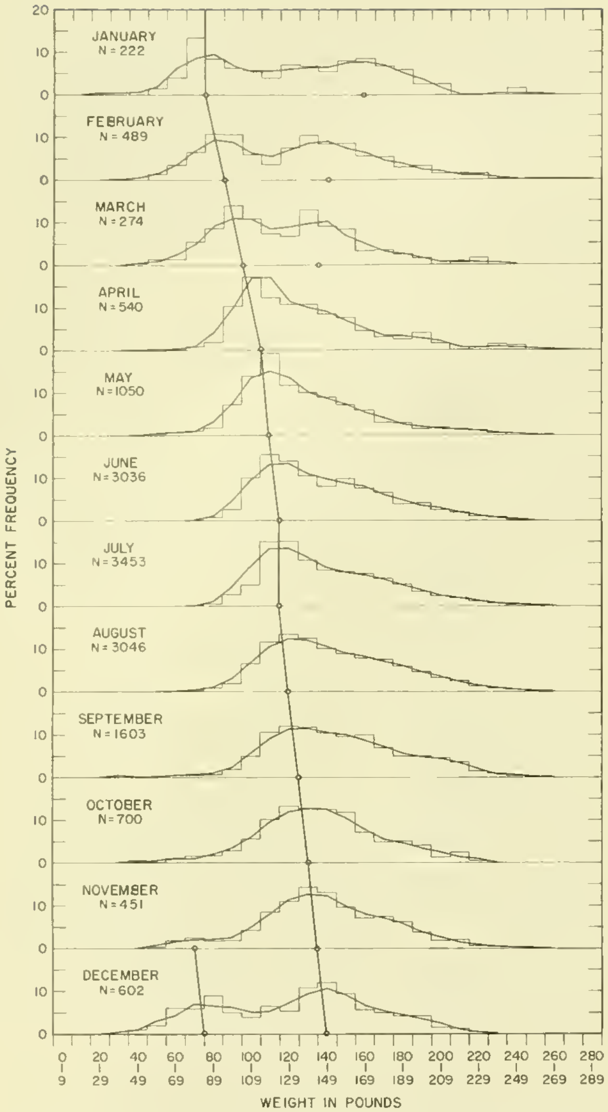

Figure 6.--Monthly weight-frequency distributions, as percentages, of Hawaiian yellowfin grouped for the years 1948-1953.

Although there are minor differences between the behavior of Moore's modes and that of the present modes, which are based on larger numbers of fish, in both studies the modes progress in a manner suggestive of growth. Moore, in referring to his 1948 data, says"....the progression of the modes representing this group /N/ indicates gradual growth until June, followed by a 5-month period in which no growth is indicated." In the combined data used here the positions of the modes indicate a weight gain of about 15 pounds (from 120 to 135 pounds) between June and October. There is a hint of slackening of growth during the months of June and July (fig. 6), but this is a shorter period than is suggested by Moore. The October through December "rapid growth" depicted by Moore is also not evident in the combined data, in fact, the growth rate during this period is less than during the early months of the year.

Equatorial Yellowfin

Initially, samples of yellowfin tuna from equatorial waters were examined by area, sex, and time of year with the individual years treated independently. A few of the individual samples were large enough to show reliable modes, but in most it was virtually impossible to locate them. Hence, years were pooled to minimize the fluctuations characteristic of small samples. Because Murphy and Shomura (1953) pointed out a longitudinal size gradient, the data from two large equatorial areas were examined independently. These are the central Pacific (155° W.-180° longitude) and the Trust Territory (134° E.-179° E. longitude), the latter being the area of operations of the Japanese mothership expeditions.

Sexual Differences in the Catch

The difference in size of the sexes and the unequal sex ratio found in the Hawaiian yellowfin are also evident in samples from along the Equator (fig. 7). Examination of nearly 4,000 longline-caught yellowfin taken throughout the year in the equatorial region showed an average ratio of 1:0.6 in favor of the males. The ratios of the individual samples did not deviate greatly, except for a sample taken during December 1953 in the central Pacific (John R. Manning cruise 18) which had a 1:1 ratio, the lowest proportion of males present in any sample and except for another sample which had a 1:0.4 sex ratio in favor of males[3/].

The observation has been made by various authors (p. 3) that below about 80-90 pounds equatorial yellowfin occur in a sex ratio of about 1:1, while above this size there is a ratio of 1:0.6 in favor of males. Murphy and Shomura (1953) suggest that the change in sex ratio in favor of males in the larger fish may result from "differential growth or mortality." Each of these possibilities is examined by comparing the size distributions of the sexes in several samples.

[3/] A sample of 545 yellowfin from Cavalieri cruise during August-September 1952. Catches not included because the majority of fishing was farther to the east than other samples.

If in this species the sexes were subject to differential mortality but not to differential growth, the observed male and female modal groups should be nearly identical in position prior to the onset of the differential mortality, the sex ratio changing as the mortality occurs. This is not definitely indicated; rather, there is some evidence suggesting differential growth.

In figures 7 and 8 it can be seen that among the prominent modal groups the female curves are displaced to the left of the males. A clearer displacement of the female mode would be evident if the frequencies were given as percentages instead of absolute numbers, for when absolute numbers are used the left tail of the male modal group conceals the displacement of the left tail of the female modal group.

Size Differences with Area

An increase in the mean size of yellowfin in longline samples taken along the Equator from west to east has been noted (Murphy and Shomura 1953). The present analysis involves yellowfin caught in two areas bounded by about the same latitudes (0°-5°N.) but by different longitudes: 155°W. to 180° and 140°E. to 179°E. (fig. 1). The distributions for the central equatorial (155°W.-180°) area are in figures 7 and 8; those for the more westerly area are shown in figure 9. Although,

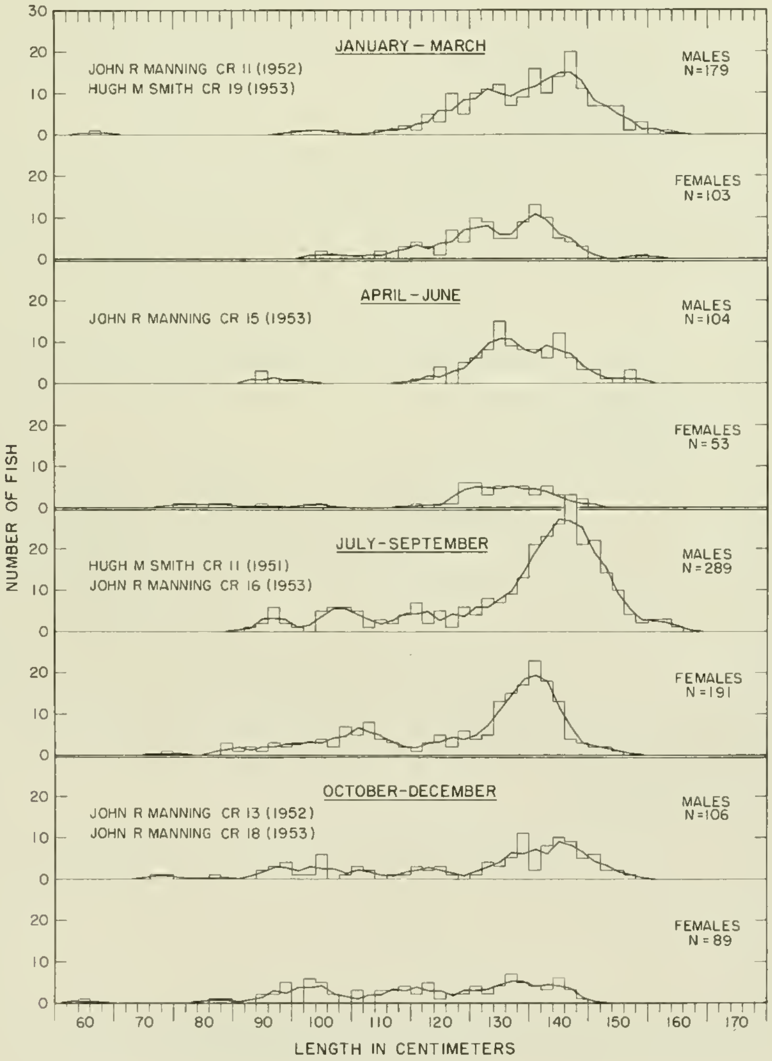

Figure 7.--Length-frequency distributions of equatorial yellowfin from 155°W. to 180° longitude taken during 1951-1953.

of necessity, the sexes have been grouped in the latter, it is unlikely that size differences between the sexes will affect the conclusions.

Throughout the year in the central equatorial Pacific the modal length of the group of larger yellowfin is between 145 and 150 cm. (131-145 pounds) (figs. 7, 8). In the western Pacific (140°E.-179°E.)[4], however, the modal length of the group of larger yellowfin was nearly always between 127 and 137 cm. (88-110 pounds) (fig. 9). However, the secondary modal group centers near 110 cm. (57 pounds) for both areas throughout the year. Thus, at all seasons there is a marked difference in the average size of the group of larger yellowfin present in these two areas and similarity between the secondary modes.

[4] These measurements are taken from Murphy and Otsu (1954), pages 16-17. These authors have used 5-cm. size groupings.

Interyear Size Variation

Because of inadequate samples, it is not possible to examine the equatorial yellowfin thoroughly for variation in modal size between years, though the evidence suggests little year-to-year fluctuation in modal position. For instance, the important modes for the 1951 through 1953 samples (fig. 7) from the central

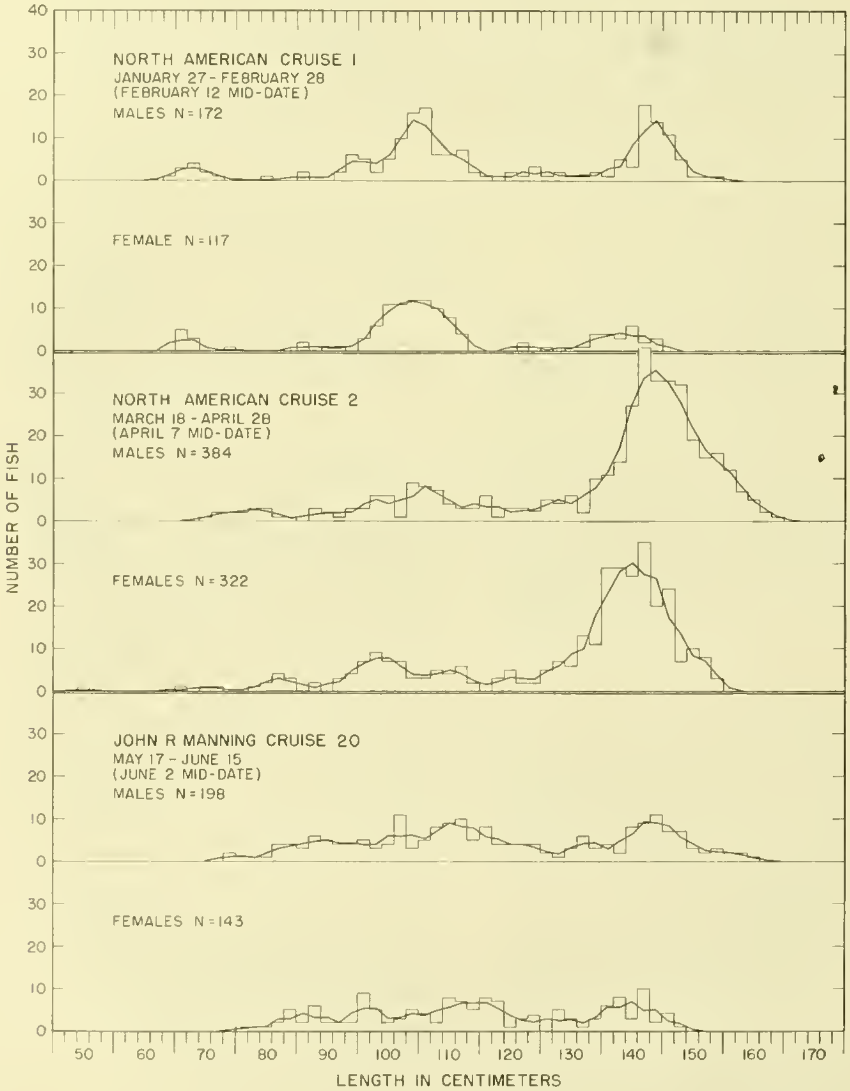

Figure 8.--Length-frequency distributions of equatorial yellowfin from 155°W. to 165°W. longitude taken during 1954.

equatorial region were located in the same positions as in the early months of 1954 (fig. 8). This is also true in the western Pacific, where the modes were similar in 1950 and 1951.

Intrayear Size Variation

A progression of modes from month to month during the growing season would be expected in a closed population if the modes represent year classes. However, there is no progression in the length-frequency distributions of male and female equatorial yellowfin taken by longline gear in the central area (fig. 7). Another good time series with data segregated by sex is available for the period January 27 through June 15, 1954 (fig. 8). Again there is little or no modal progression. One item of interest is the change in relative numbers of the two size groups (fig. 8); in January-February the smaller sizes (90-120 cm.) (upper panels) predominated, while during March-April the larger fish (130-170 cm.) were most numerous in the catch. This change in the relative numbers of the dominant sizes probably reflects the fact that the earlier sample was taken closer to land, for as pointed out in Shomura and Murphy (1955), samples from the vicinity of islands contain a higher percentage of small fish than those from well offshore.

It can be seen in figure 9 that the modal groups (with the sexes combined) do not progress in the western Pacific either, though

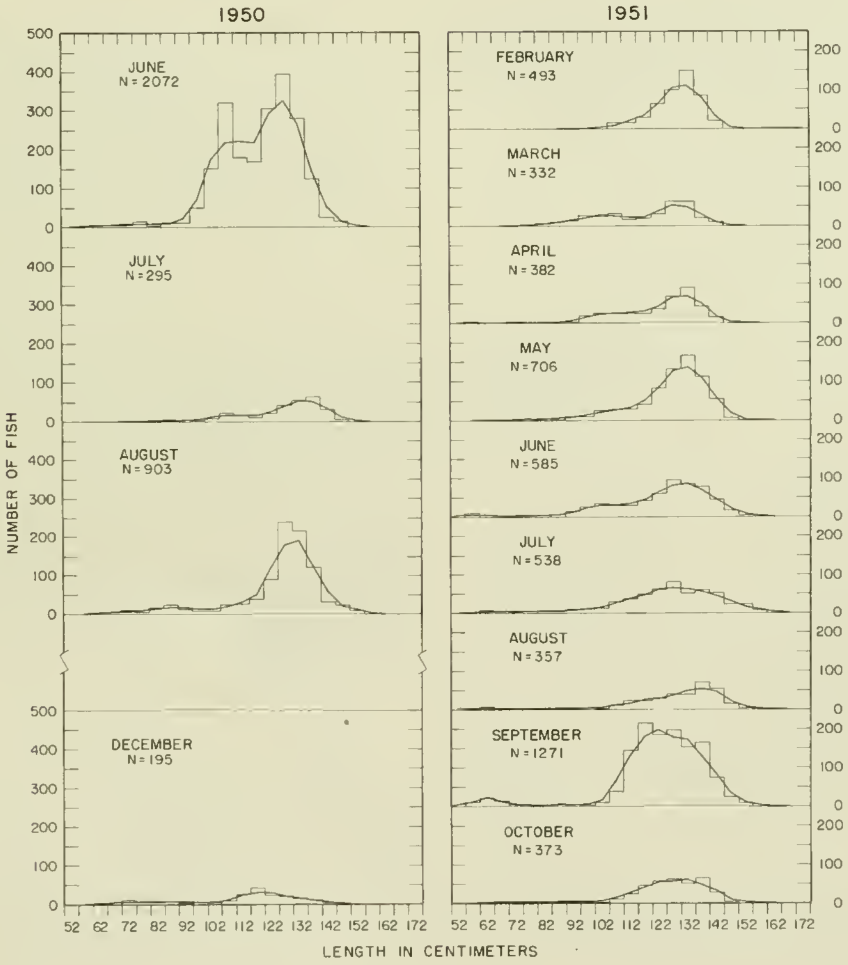

Figure 9. --Length-frequency distributions of yellowfin measured on Japanese mothership expeditions, 140°E. to 179°E. longitude.

there are minor shifts. During July, 1950 and August and September, 1951 there is some change in the prominent modes, and in the December, 1950 sample the large mode is displaced 15 cm. to the left. This last anomaly probably reflects the location of the catch, for this sample was taken farther west than the others.

While it is somewhat surprising not to find modal progression in equatorial yellowfin, it is not difficult to propose a hypothesis to account for its absence. Perhaps any given area (considering only the restricted ecological niche sampled by the longline) is occupied by yellowfin of a restricted size because there is constant ingress of smaller fish and egress of larger fish. This would obscure evidence of growth of the dominant size groups and in fact occasionally produce what appears to be negative growth, found to some extent in almost all time series data from equatorial waters. This may not apply in the Hawaiian area, where the seasonal presence of a population of deep-swimming yellowfin and the scarcity of small fish (Murphy and Ikehara 1955) suggest that major recruitment to the deep-swimming population (the group sampled by the longline) takes place elsewhere.

COMPARISON OF SIZE DISTRIBUTIONS FROM THE CENTRAL AND WESTERN PACIFIC

Although there is no evidence that the dominant size groups present represent age classes of fish at the Equator, it is of interest to compare the size distributions of longline-caught yellowfin from all areas in the central and western Pacific. Samples with a mid-date during or near February are compared because this is the only time of year for which data are available from all areas and it is necessary to relax the definition of a mode for this comparison as there are relatively few measurements. Samples from different years are used, but it has been shown that there is little difference in modal positions from year to year in a given area. (The Hawaiian size distribution for February 1948-1953 was converted from pounds to centimeters for ready comparison with the other data.)

Figure 10 shows these distributions with the modes indicated by arrows. There are four modal sizes, two or more of which appear in each locality. This agreement in modal position is also shown in table 2, and it can be seen that the distances between modes are nearly identical, except for the central equatorial Pacific (155°W.-165°W. longitude).

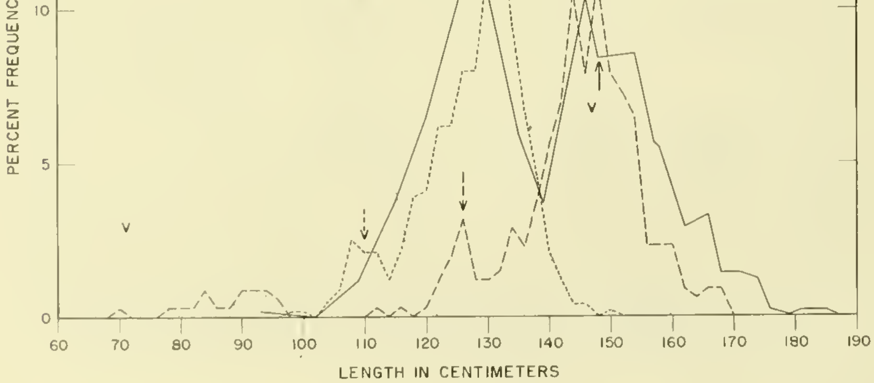

Figure 10.--Comparison of yellowfin size distributions from the central and western Pacific.

Table 2.--Comparison of size distributions (in cm.) from all areas. Sampling period from January 27 to April 13

Area	Recognized modal sizes (cm.)				
	I		II		III
	Position of mode	Average distance between modes	Position of mode	Average distance between modes	Position of mode
Hawaiian (1948-1953)	-	-	128	20	148
Western equatorial Pacific 156°-161°E. longitude (1951)	-	-	110	22	132
Central equatorial Pacific 155°-165°W. longitude (1954)	71	38	109	36	147
American Samoa (1954)	-	-	127	20	147

The fact that we find approximately the same size increments between modes in these several areas (except the central equatorial Pacific) could indicate a possibility of extensive migration and intermingling of the stocks, however, morphometric studies (Royce 1953) indicate little intermingling between areas as widely separated as these. The distance between the modes in the central equatorial distribution (fig. 10) suggests the absence of one of the dominant size groups, i. e., in the other three areas there are dominant groups present between the central equatorial modes at approximately 109 cm. and 147 cm. Whether or not these groups are annual in occurrence is speculative, but the similarity in their positions and the dissimilarity in their relative strength among areas suggests the possibility of similar spawning and growing patterns throughout this vast region as well as that of extensive migration despite Royce's conclusions.

DISCUSSION

There is a consistent progression of modes in size-frequency plots of Hawaiian longline-caught yellowfin. It is unfortunate that large samples of measurements separated by sex are not available throughout the year so that the nature of the apparent change in growth rate for the latter half of each year could be more carefully analyzed. Such samples might show this change in growth rate to be associated with differential migration patterns or the ingress of slower growing fish.

Kishinouye (1923), in speaking of scombroids in general, says "Generally the male fish come first, in the middle of the fishing season the number of both sexes is nearly equal, and at the end of the season the female fish predominate." This might account for the apparent reduction in growth rate except for the fact that the sex ratio appears to be constant during the months of highest availability, and during the period of changing growth rate.

Spawning may account for a reduced growth in weight due to a physiological strain on the female fish plus the loss of eggs. Van Oosten and Hile (1949) conclude that "female Lake Erie whitefish /Coregonus clupeiformis (Mitchill)/ lose approximately 11 percent of their weight at spawning" and it is well known that checks which correlate well with spawning time are laid down on the scales of some species. The spawning period of Hawaiian yellowfin agrees well with the time of change in growth rate, but there is apparently no resumption of the prespawning rate as soon as the spawning period is over.

At the Equator the yellowfin size-frequency distributions from any one area consist of a series of dominant size groups which do not appear to grow. The presence of modes indicates a limited spawning season or perhaps an extended spawning season with peaks of activity at certain times, for it is

not probable that intermittent egg or larval losses would result in dominant peaks such as are seen in the size-frequency distributions, especially since they appear at the same size each year. Alternately, a very restricted and rigid size selection by longline gear could be occurring in the midwater environment fished by longlines causing the appearance of sharp peaks in the size frequencies; in this case age groups would not be evident in longline samples. Until the migratory habits are clearly understood and we are better able to sample segments of the whole population it is doubtful that size-frequency studies will produce a description of growth.

SUMMARY

1. Male yellowfin in Hawaii attain greater size than females. The sex ratio in the Hawaiian fishery is about 1:0.6 in favor of the males, and this ratio is fairly stable throughout the year.

2. In the Hawaiian fishery there are no great year-to-year differences in the yellowfin size distribution.

3. Smaller yellowfin (100-130 pounds) enter the fishery in June and July and the larger fish (>130 pounds) in August and September.

4. Yellowfin size measurements for 1948-1953, while agreeing in general with the growth rate described by Moore (1951), suggest that the no-growth period he reported (June to October) is not real, though there seems to be a slackening of the growth rate in the latter half of each year.

5. The equatorial yellowfin exhibit the same size-composition characteristics as the Hawaiian specimens, namely size differences between sexes, and only minor differences between years.

6. In the equatorial region there is no modal progression with time.

7. Examination of size-frequency distributions from the western equatorial Pacific, central equatorial Pacific, and Hawaiian Islands indicates that when modes do occur they are all in similar positions, and that certain modal groups are frequently or consistently missing from distributions in the central and western equatorial samples.

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APPENDIX

Table 3.--Weight frequencies of Hawaiian yellowfin, April through September, 1951

Class interval	Males	Females
lbs.		
70- 79	1	1
80- 89	1	2
90- 99	3	9
100-109	8	20
110-119	22	32
120-129	32	27
130-139	36	19
140-149	18	10
150-159	17	19
160-169	18	11
170-179	29	4
180-189	25	2
190-199	14	2
200-209	10	3
210-219	11	-
220-229	6	-
230-239	3	-
240-249	1	-
250-259	1	-
260-269	-	-
Total	256	161

Table 4.--Weight frequencies of Honolulu yellowfin tuna landings, sexes combined, 1950*

Class interval	Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
lbs.												
30- 39	1	-	-	-	-	-	3	-	-	1	1	-
40- 49	-	-	-	-	1	-	-	-	-	-	1	-
50- 59	1	-	-	-	2	-	-	1	2	-	-	3
60- 69	-	3	-	-	2	1	-	2	-	-	-	3
70- 79	4	5	1	1	4	2	1	3	1	1	2	5
80- 89	5	10	2	1	3	4	6	5	1	2	1	5
90- 99	7	8	3	2	7	13	18	16	4	5	2	3
100-109	4	8	2	7	10	43	63	45	10	5	12	3
110-119	1	5	3	10	24	79	101	81	29	4	18	11
120-129	1	4	2	2	12	77	134	116	41	18	23	11
130-139	-	1	3	3	8	81	102	133	35	25	30	18
140-149	2	1	1	1	4	39	65	85	38	21	35	27
150-159	-	1	2	-	6	39	44	56	33	19	19	18
160-169	1	4	1	2	3	21	32	38	26	7	19	11
170-179	-	1	1	1	1	19	29	42	29	7	14	4
180-189	1	-	-	-	1	13	22	36	13	10	8	2
190-199	-	-	-	-	1	15	15	21	22	5	7	8
200-209	-	-	-	-	-	7	4	20	14	1	3	1
210-219	-	-	-	-	-	2	10	11	24	4	3	-
220-229	-	1	-	-	-	2	6	11	14	1	-	-
230-239	-	-	-	-	-	5	3	11	5	1	-	-
240-249	-	-	-	-	-	-	3	3	3	1	-	-
250-259	-	-	-	-	-	-	1	1	-	-	-	-
260-269	-	-	-	-	-	-	-	1	-	-	-	-
Total	28	52	21	30	89	462	662	738	344	138	198	133

* Weight frequency tables covering November and December of 1947 and all months of 1948 and 1949 can be found in Moore (1951).

Table 5.--Weight frequencies of Honolulu yellowfin tuna landings, sexes combined, 1951

Class interval	Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
lbs.												
50- 59	-	2	-	1	-	-	-	-	1	1	-	-
60- 69	2	5	2	-	1	-	-	-	2	4	2	-
70- 79	2	5	5	2	2	1	1	1	2	1	5	-
80- 89	-	9	6	4	3	2	-	5	-	1	2	-
90- 99	3	14	12	22	16	9	15	3	9	-	2	2
100-109	-	7	11	31	47	61	34	17	9	4	1	3
110-119	-	4	3	21	98	111	86	35	26	9	4	-
120-129	1	5	2	15	49	101	97	61	40	27	4	-
130-139	3	7	6	14	30	56	49	48	38	17	7	3
140-149	2	10	3	15	25	30	28	37	41	20	6	4
150-159	3	10	3	4	20	59	37	32	24	28	6	1
160-169	5	6	-	4	8	40	23	35	44	14	4	1
170-179	6	4	-	-	7	29	36	32	20	6	4	1
180-189	5	2	-	-	5	25	29	29	20	6	4	2
190-199	2	4	-	-	4	17	9	18	14	2	2	1
200-209	3	3	-	-	2	12	9	12	12	2	-	1
210-219	-	-	-	-	-	7	10	11	9	2	2	2
220-229	-	1	-	-	2	8	4	6	1	-	1	1
230-239	-	-	-	-	1	4	3	2	3	-	-	-
240-249	-	-	-	-	-	-	2	2	1	-	-	-
250-259	-	-	-	-	1	3	2	3	1	-	-	-
260-269	-	-	-	-	-	-	-	-	1	-	-	-
Total	37	98	53	133	321	575	474	389	318	144	56	22

Table 6.--Weight frequencies of Honolulu yellowfin tuna landings, sexes combined, 1952

Class interval	Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
lbs.												
30- 39	-	-	-	-	-	-	-	-	1	-	-	-
40- 49	-	-	-	-	-	1	-	1	2	1	-	2
50- 59	-	-	1	1	-	-	-	-	1	-	-	3
60- 69	1	3	1	-	-	-	-	-	-	-	2	10
70- 79	1	3	3	-	3	-	-	2	-	1	-	9
80- 89	-	7	3	-	4	3	4	5	2	-	-	14
90- 99	1	10	7	6	8	15	13	16	3	-	-	9
100-109	-	6	8	15	35	52	63	31	8	3	1	4
110-119	-	3	5	12	43	107	109	79	17	3	1	3
120-129	3	9	4	10	26	127	125	95	31	9	3	5
130-139	3	8	9	8	24	78	106	79	36	13	5	15
140-149	3	7	4	9	30	60	65	65	32	7	5	13
150-159	2	7	5	13	24	67	60	56	22	12	2	12
160-169	2	5	4	2	21	68	64	58	18	1	2	9
170-179	-	2	1	3	12	55	41	45	21	5	2	9
180-189	1	5	2	-	7	30	44	34	8	5	4	7
190-199	1	5	1	2	3	34	24	29	18	6	2	7
200-209	-	1	-	2	4	17	23	16	11	1	-	3
210-219	-	2	1	-	3	20	12	17	5	3	2	2
220-229	-	-	1	-	3	6	15	19	7	1	1	1
230-239	-	-	-	2	1	10	10	6	3	-	1	-
240-249	-	-	-	-	-	4	2	6	1	-	-	-
250-259	-	-	-	-	-	4	-	1	-	-	-	-
260-269	-	-	-	-	-	1	2	1	1	-	-	-
Total	18	83	60	85	251	759	782	661	248	71	33	137

Table 7.--Weight frequencies of Honolulu yellowfin tuna landings, sexes combined, 1953

Class interval	Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
lbs.												
40- 49	-	-	-	-	-	-	-	-	-	-	-	1
50- 59	1	-	2	-	-	-	-	-	-	1	1	3
60- 69	1	2	-	-	2	-	1	-	-	-	2	15
70- 79	4	4	2	1	-	1	-	-	-	-	2	14
80- 89	5	6	6	4	3	2	2	2	-	2	3	17
90- 99	1	9	5	16	13	12	18	5	5	-	-	5
100-109	3	4	5	20	13	30	51	25	9	3	-	6
110-119	6	4	4	13	11	52	56	28	18	11	4	11
120-129	6	15	10	6	12	17	39	36	11	4	3	10
130-139	4	21	11	16	16	22	24	22	19	4	3	14
140-149	3	15	10	9	12	31	47	35	18	11	1	17
150-159	8	7	5	16	10	42	54	39	18	6	5	14
160-169	6	5	-	10	7	35	43	27	14	9	-	6
170-179	4	11	8	6	4	37	38	34	12	5	4	7
180-189	3	2	3	10	12	25	24	14	4	4	1	6
190-199	2	3	2	17	4	25	21	12	3	3	2	3
200-209	1	2	-	6	4	9	11	10	7	2	2	-
210-219	-	3	-	-	6	14	11	15	6	1	1	1
220-229	-	5	2	3	3	6	11	3	-	-	-	1
230-239	-	1	-	5	2	1	4	5	3	-	-	-
240-249	2	-	-	5	1	3	3	4	-	-	-	-
250-259	-	1	-	-	-	-	1	-	-	-	-	-
260-269	-	1	-	-	-	-	1	-	-	-	-	-
270-279	-	1	-	-	-	-	-	-	-	-	-	-
280-289	-	-	-	1	-	-	-	-	-	-	-	-
290-299	-	-	-	1	-	-	-	-	-	-	-	-
Total	60	122	75	165	135	364	460	316	147	66	34	151

Table 8.--Yellowfin length frequencies by sexes, 155°W. to 170°W. longitude, 1951 through 1953

Class interval (cm.)	January-March				April-June		July-September				October-December			
	HMS-19 Jan. 23- Feb. 5, 1953		JRM-11 Feb. 1- Mar. 12, 1952		JRM-15 May 28- June 9, 1953		JRM-16 July 25- Aug. 27, 1953		HMS-11 Sept. 12-16, 1951		JRM-13 Nov. 19-28, 1952		JRM-18 Dec. 1-15, 1953	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
64- 65	-	-	-	-	-	-	-	-	-	-	-	1	-	-
66- 67	1	-	-	-	-	-	-	-	-	-	-	-	-	-
68- 69	-	-	-	-	-	-	-	-	-	-	-	-	1	-
78- 79	-	-	-	-	-	-	-	1	-	-	-	-	1	-
80- 81	-	-	-	-	-	1	-	-	-	-	-	-	-	-
82- 83	-	-	-	-	-	1	-	-	-	-	-	-	-	-
84- 85	-	-	-	-	-	-	-	-	-	-	-	-	-	-
86- 87	-	-	-	-	-	1	-	-	-	-	-	-	1	1
88- 89	-	-	-	-	-	1	-	3	-	-	-	-	-	1
90- 91	-	-	-	-	-	-	-	1	-	-	-	-	-	-
92- 93	-	-	-	-	-	-	1	1	-	1	-	-	-	-
94- 95	-	-	-	-	3	1	2	1	-	-	-	-	2	2
96- 97	-	-	-	-	-	-	6	2	-	1	-	-	3	2
98- 99	-	-	-	-	1	-	1	2	1	-	-	-	4	5
100-101	-	-	1	-	1	-	1	3	-	-	-	-	1	-
102-103	1	-	-	-	-	1	-	3	-	-	-	-	1	6
104-105	1	2	-	-	-	1	5	3	-	1	-	-	6	5
106-107	1	1	-	-	-	-	5	2	1	-	-	-	-	2
108-109	-	-	-	1	-	-	6	6	-	1	-	-	1	-
110-111	-	-	-	1	-	-	4	5	1	-	-	-	3	3
112-113	-	-	-	-	-	-	1	7	-	1	-	-	2	-
114-115	1	-	-	2	-	-	2	3	1	1	-	-	-	3
116-117	-	-	1	-	-	-	2	3	-	-	-	1	1	2
118-119	-	1	2	2	-	-	2	2	2	-	-	-	1	4
120-121	-	1	1	3	1	1	6	1	1	-	-	-	3	2

Table 8.--Yellowfin length frequencies by sexes, 155°W. to 170°W. longitude, 1951 through 1953 (cont'd)

Class interval (cm.)	January-March				April-June		July-September				October-December			
	HMS-19 Jan. 23-Feb. 5, 1953		JRM-11 Feb. 1-Mar. 12, 1952		JRM-15 May 28-June 9, 1953		JRM-16 July 25-Aug. 27, 1953		HMS-11 Sept. 12-16, 1951		JRM-13 Nov. 19-28, 1952		JRM-18 Dec. 1-15, 1953	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
122-123	1	1	4	2	1	-	1	3	1	-	-	2	2	3
124-125	1	1	2	-	4	1	5	4	-	1	2	-	1	1
126-127	3	2	7	5	-	1	1	2	-	-	-	-	1	2
128-129	2	-	3	4	5	6	5	6	1	-	-	1	-	1
130-131	5	4	5	6	6	6	4	3	-	1	-	3	1	1
132-133	7	5	4	4	8	3	5	3	3	2	3	1	1	1
134-135	7.	2	5	3	15	5	5	10	2	3	2	3	1	1
136-137	1	1	6	4	9	5	4	8	5	7	3	1	2	6
138-139	5	3	4	6	8	5	8	14	5	3	9	1	2	4
140-141	3	1	13	12	8	3	11	21	10	2	1	-	1	4
142-143	1	2	9	8	6	5	23	15	-	3	3	1	5	2
144-145	2	2	12	3	12	3	22	9	4	4	2	-	8	6
146-147	3	1	17	3	6	-	28	4	5	-	2	1	7	2
148-149	5	-	6	3	3	2	14	2	7	1	2	-	3	1
150-151	3	-	4	-	3	-	17	2	5	-	3	-	3	-
152-153	5	-	2	-	1	-	11	2	3	-	-	-	2	-
154-155	2	-	5	-	-	-	9	1	1	-	-	-	2	-
156-157	1	-	-	-	3	-	4	-	-	-	-	-	1	-
158-159	2	1	1	-	-	-	2	-	-	-	-	-	-	-
160-161	-	-	-	-	-	-	3	-	-	-	-	-	-	-
162-163	1	-	-	-	-	-	3	-	-	-	-	-	-	-
164-165	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Total	65	31	114	72	104	53	230	158	59	33	32	16	74	73

Table 9.--Length frequencies of equatorial yellowfin by sexes, Line Islands area, 1954

Class interval	North American cruise 1 (1/27-2/28)		North American cruise 2 (3/18-4/28)		John R. Manning cruise 20 (5/17-6/15)	
	M	F	M	F	M	F
cm.						
54- 55	-	-	-	1	-	-
56- 57	-	-	-	-	-	-
58- 59	-	-	-	-	-	-
60- 61	-	-	-	-	-	-
62- 63	-	-	-	-	-	-
64- 65	-	-	-	-	-	-
66- 67	-	-	-	-	-	-
68- 69	1	-	-	-	-	-
70- 71	3	5	-	1	-	-
72- 73	4	3	-	-	-	-
74- 75	2	-	1	1	-	-
76- 77	1	-	2	1	-	-
78- 79	-	1	2	-	2	-
80- 81	-	-	2	-	1	1
82- 83	-	-	3	1	1	1
84- 85	1	-	3	2	1	1
86- 87	-	-	1	4	4	2
88- 89	-	-	1	3	4	5
90- 91	2	2	-	-	3	2
92- 93	-	-	3	2	6	6
94- 95	-	1	2	-	5	2
96- 97	2	1	1	3	4	2
98- 99	6	-	3	4	4	2
100-101	5	3	3	7	5	9
102-103	2	6	6	9	3	5
104-105	5	11	6	7	4	2
106-107	10	11	1	7	11	3
108-109	16	12	9	3	3	5
110-111	17	12	8	3	5	4
112-113	6	10	7	5	8	2
114-115	6	8	4	4	9	8
116-117	7	4	3	6	10	7
118-119	2	-	3	2	5	5
120-121	1	-	6	-	8	8
122-123	-	-	1	3	4	7
124-125	2	-	3	5	4	1
126-127	1	2	3	2	4	3
128-129	3	-	2	2	4	4
130-131	1	1	5	5	2	-
132-133	2	-	4	7	1	5
134-135	1	1	6	6	3	3
136-137	1	1	2	13	6	1
138-139	2	4	10	11	3	3
140-141	1	4	11	29	4	6
142-143	5	3	14	29	2	8
144-145	3	6	27	27	8	3
146-147	18	2	41	35	9	10
148-149	14	3	33	20	11	2
150-151	11	-	33	24	7	4

Table 9.--Length frequencies of equatorial yellowfin by sexes, Line Islands area, 1954 (cont'd)

Class interval	North American cruise 1 (1/27-2/28)		North American cruise 2 (3/18-4/28)		John R. Manning cruise 20 (5/17-6/15)	
	M	F	M	F	M	F
cm.						
152-153	5	-	32	7	7	1
154-155	1	-	19	10	3	-
156-157	1	-	15	8	2	-
158-159	1	-	16	3	3	-
160-161	-	-	12	-	2	-
162-163	-	-	7	-	2	-
164-165	-	-	5	-	1	-
166-167	-	-	2	-	-	-
168-169	-	-	1	-	-	-
Total	172	117	384	322	198	143

Table 10.--Length frequencies of equatorial yellowfin from American Samoan waters, January 28 to April 13, 1954

Class interval	Sexes combined	Class interval	Sexes combined
cm.		cm.	
70- 71	1	120-121	2
72- 73	-	122-123	3
74- 75	-	124-125	6
76- 77	-	126-127	12
78- 79	1	128-129	4
80- 81	1	130-131	4
82- 83	1	132-133	5
84- 85	3	134-135	10
86- 87	1	136-137	8
88- 89	1	138-139	13
90- 91	3	140-141	19
92- 93	3	142-143	22
94- 95	3	144-145	36
96- 97	3	146-147	31
98- 99	-	148-149	37
100-101	-	150-151	28
102-103	1	152-153	25
104-105	-	154-155	22
106-107	-	156-157	8
108-109	-	158-159	8
110-111	-	160-161	8
112-113	1	162-163	3
114-115	-	164-165	2
116-117	1	166-167	3
118-119	-	168-169	3
Total			346

Table 11.--Yellowfin tuna weights estimated from lengths by the formula log weight (lbs.) = -7.3548 + 2.9959 log length (mm.), based on measurements of 202 yellowfin captured in Hawaiian waters during the months January to September, 1948 and 1949 (about half the measurements were taken in June and July)

Length	Weight	Length	Weight	Length	Weight	Length	Weight
cm.	lbs.	cm.	lbs.	cm.	lbs.	cm.	lbs.
40	2.8	80	22.0	120	74.2	160	175
41	3.0	81	22.8	121	76.0	161	179
42	3.2	82	23.7	122	77.9	162	182
43	3.4	83	24.6	123	79.8	163	186
44	3.7	84	25.5	124	81.8	164	190
45	3.9	85	26.4	125	83.8	165	192
46	4.2	86	27.3	126	85.8	166	196
47	4.5	87	28.3	127	87.9	167	200
48	4.8	88	29.3	128	90.0	168	203
49	5.1	89	30.3	129	92.1	169	207
50	5.4	90	31.3	130	94.2	170	210
51	5.7	91	32.4	131	96.4	171	214
52	6.0	92	33.4	132	98.6	172	218
53	6.4	93	34.6	133	101	173	222
54	6.8	94	35.7	134	103	174	226
55	7.2	95	36.8	135	106	175	230
56	7.6	96	38.0	136	108	176	234
57	8.0	97	39.2	137	110	177	238
58	8.4	98	40.4	138	113	178	242
59	8.8	99	41.6	139	115	179	246
60	9.3	100	42.9	140	118	180	250
61	9.8	101	44.2	141	120		
62	10.2	102	45.6	142	123		
63	10.8	103	46.9	143	125		
64	11.3	104	48.3	144	128		
65	11.8	105	49.7	145	131		
66	12.4	106	51.1	146	134		
67	12.9	107	52.6	147	137		
68	13.5	108	54.1	148	139		
69	14.1	109	55.6	149	142		
70	14.8	110	57.1	150	145		
71	15.4	111	58.7	151	148		
72	16.0	112	60.3	152	150		
73	16.7	113	61.9	153	154		
74	17.4	114	63.6	154	156		
75	18.1	115	65.3	155	160		
76	18.9	116	67.0	156	163		
77	19.6	117	68.7	157	166		
78	20.4	118	70.5	158	169		
79	21.2	119	72.3	159	172		